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# The Biophysical Modelling of the Circulatory Apparatus

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**Abstract**
The circulatory apparatus has as a main function the constant maintaining of the internal environment in all the regions of the organism. The capillary as morphofunctional unit represents a biological membrane with selective permeability. The big circulation (systemic) starts in the left ventricle, through the aortic artery. The aortic system is made of the aortic artery and its branches, which irrigate all the tissues and organs of the human body. The blood is a liquid tissue, being formed of a fundamental substance – plasma and blood cells. The report between the plasma and figurate elements is 55:45. Excitability is the property of the heart's muscle to respond through a contraction to certain mechanical, physical or chemical excitants. The period which includes a single contraction (systole) and a single relaxation (diastole) is called cardiac cycle. The author's unique hypothesis is that of the circulatory apparatus in the human organism have a control system which he calls the "hypothetical secondary brain". In the everyday regulation of the human body the functioning of these "hypothetical secondary brains" is suppressed by the regulation of the whole organism, but with tremendous probability, space-microscopy will prove the validity of this hypothesis in the near future.

**Keywords:** biophysical modelling, circulatory apparatus, hypothetical secondary brains



## Introduction

The circulatory apparatus has as a main function the constant maintaining of the internal environment in all the regions of the organism. It is made of a central muscular cavity organ adapted to the function of blood propulsion – the heart and a vascular system. The vascular system is a closed tubular system, made of a series of pipes, structurally adapted to the function of blood propulsion and circulation. It is represented by arteries, capillaries, veins and lymph vases. [1]

All the vases are padded internally with an endothelium which is surrounded according to certain specific mechanical and hemodynamic conditions which will form together the vascular wall. These structures are: collagen and reticulate fibres, elastic fibres, smooth muscular fibres. The

vases are dynamic structures characterized by a great plasticity and adaptive capacity, their structure being partially dependent on the functional state of those organs. This fact explains the modification in biophysical limits of the vases in the pregnant uterus, in the lactating mammal gland, in the atrophic glands. The capillaries are represented by very thin canals with a diameter between 4–30 μm. These structures are present in all the organs and tissues under the aspect of variable size and form networks according to the morphofunctional features of that organ. [2] The capillary vases as morphofunctional units have a great plastic and regenerative capacity.

The capillary walls have a specific property, which is permeability. The capillary as morphofunctional unit represents a biological membrane with selective permeability. The exchanges between blood and tissues can be obtained in the following ways: a) passive transportation due to the concentration difference, this way water and small molecules can pass though; b) active transfer which is obtained through pinocytosis and endocytosis; c) the interendotelial transport at the pore level. [3]

In the composition of the vascular tree there are two circulation territories: great circulation and small circulation. Small circulation (pulmonary) starts in the right ventricle, through the pulmonary tree, which transports $CO_2$ blood towards the lung. The pulmonary tree is divided in the two pulmonary arteries which take the blood towards the perialveolar capillary network where they pass it to the alveoli which eliminate it through expiration. The oxygenated blood is collected by the pulmonary veins, two for each lung. The four pulmonary veins end in the left atrium. [4]

The big circulation (systemic) starts in the left ventricle, through the aortic artery. The aortic system is made of the aortic artery and its branches, which irrigate all the tissues and organs of the human body. The aortic system transports the oxygenated blood and the nutritive substances towards the tissues and the organs. At this level they are diffused in all the tissues and organs, the capillary system of small calibre of 4–12 μm. From this point, the veins with blood loaded with carbon dioxide is taken by the two veins which lead it in the left atrium – through the venous circulation – the lymph arrives as well and it is collected by the lymph system. The lymph, as well as the interstitial liquid has a composition similar to the one of the blood plasma, with the mention of existence of a small percentage of proteins compared to the blood plasma.

**The structure**

The blood is a liquid tissue, being formed of a fundamental substance – plasma and blood cells. The report between the plasma and figurate elements is 55:45. The characteristic red colour is determined by the presence of haemoglobin fixed weakly on the red cells. Structurally, blood is a tissue adapted for various functions: transport (of respiratory gases), of the deassimilation substances, defence, adjustment and integration, participating to thermoadjustment processes. [5]

Blood cells are represented through nucleate cells: leucocytes (6000–8000 in $mm^3$), through anucleate cells – erythrocytes or red cells ($4{,}5.10^6$ in $mm^3$ in men and $4.10^6$ in women) and through thrombocytes (200.000–500.000 in $mm^3$).

Heart is the central organ of the cardiovascular apparatus. The blood axis is obliquely pointed downwards, in left and forwards, so that 1/3 from the heart is places at right and 2/3 on the left of the median sagittal plan of the body. The heart's weight is 250–300 g. The heart is formed of two cavities: two atriums and two ventricles. The orifices which are found in the cavities have valves. For example the right atrioventricular orifice has the tricuspid valve and the left one has the bicuspid valve. [6]

From the structural point of view, the heart is formed of two tunics, which are from the outside to the inside: pericardium, myocardium and endocardium. The muscles of the atria are completely separated from the muscles of the ventricle, the anatomic and function connection is realized by the embryonal tissue (nodal tissue). The nodal tissue differs from the execution one through the irregular arrangement of the myofibrils, forming networs. The nodal tissue includes the Keith-Flack sinoatrial node, the Aschoff-Tawara atrioventricular node, the Hiss fascicle and the Purkinje net.

The heart is irrigated by the two coronary arteries. Colateral branches start from the coronary arteries, which are the terminal type, irrigating certain territories from the myocardium and it does not bond through anastomosis with the

neighbouring branches. Of one of these collaterals is obstructed, that territory does not receive nutritive substances and oxygen, they become necrosed and cause infarction. [7]

The spleen is an unpaired intraperitoneal abdominal organ which belongs to the circulatory system. It forms lymphocytes, it ruins old red cells, intervenes in the iron metabolism and it is a blood deposit organ, which it sends into circulation in case of need (haemorrhages, physical effort).

**The function**

The cell life is not possible unless new nutritive elements are brought continuously to replace the consumed ones and the products resulted from them after their activity are being removed. The blood and lymph which form the internal body environment fulfil this role.

The heart muscles have numerous biophysical properties. Excitability is the property of the heart's muscle to respond through a contraction to certain mechanical, physical or chemical excitants. [8] In the heart's activity the main mechanical excitation which exerts on the myocardium, is the distension of the heart's cavity, which causes the heart contraction. From the excitation to the response through a contraction there is a latency period of 0,01 s. The contractibility is the property of the heart muscle to modify its shape, to contract, under the influence of an exciter. The tonicity is the property of the heart muscle to have permanently (even in diastole) a slight state of contraction, called tonus. The rhythmicity is the myocardium's property to contract regularly and with a certain frequency per unit of time.

The heart's capacity to excite under the influence of the impulses appears in the myocardic system is called automatism and this represents the main feature for the functioning of the cardiac muscle. The stimulus appears in the sinoatrial node (Keith-Flack: with a frequency of 70-80/min) and it spreads in the atrial mass which contracts, then it reaches the atrioventricular node (Aschoff-Tawara: with a frequency of 40–45/min), which it excites: the stimulus produced by this node passes in the Hiss fascicle (with a frequency of 20–25/min) and it spreads in the entire muscular mass of the ventricles, through the Purkinje network (with a frequency of 10–15/min). The ventricular contraction starts this way. [9]

The period which includes a single contraction (systole) and a single relaxation (diastole) is called cardiac cycle. The cardiac cycle lasts 0,8 seconds. Each cardiac cycle starts with a contraction of the atria muscles (atrial systole 0,1 s), when they relax (atrial diastole = 0,7 s). The contraction of the ventricular muscles with a delay of 0,1 s (ventricular systole = 0,5 s). So the heart is in general relaxation (general diastole = 0,4s). After this break the cycle starts again. The cardiac muscle is never tired unless it suffered a pathological process. [10]

During the diastole, blood is aspired in the heart and during the systole it is pushed in the big and small circulation. Thanks to the heart's valvular apparatus a certain direction of blood flow is achieved, from the veins to the atria and further on in the ventricle and in the arteries, but never backwards, as long as the integrity of this valves is not touched. If we place the ear on the anterior thoracic wall, in the precordial region, we can hear the two cardiac rumours of the systoles.

The blood amount pushed from the heart in the vascular system in a certain time represents the blood flow. The blood volume that the hearts pushes in the arteries in a contraction is called systolic volume and normally it is 50–80 $cm^3$. The blood volume that the heart pushes in the vessels during a minute is called minute-volume (5000 $cm^3$).

In the normal person, at rest, in the great vessels (humeral femoral artery), the maximum pressure is approximately 120–140 mmHg and the minimum one is approximately 60 mmHg. In the aorta, hence in the wide vessels, blood flows with a speed of 0,5 m/s and in the capillaries it is 0,5 mm/s. This slowing down of the blood circulation in the capillaries favours the substance exchange between blood and tissues. [11]

If we compress an artery with the finger, we can feel those rhythmical movements called pulsations. They coincide with the cardiac systoles which propagate along the arteries walls with a higher speed (5m/s) then the blood circulation speed. [12] If we follow the pulse we can count the cardiac contractions.

* * *

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## Modelling

The first electrograms were made by Eindhoven in 1903 at Leyden, using electrodes applied in the bipolar deviation in three points on the body. The potentials collected with these electrodes represent the projections of the cardiac vectors on the exploration axes. The amplitudes of the vector at its turn is proportional with the electromotor force of the heart, whose size is a very important diagnostic mean in the medical clinic for the assessment of the heart's functioning state. At normal state the electrocardiogram presents for each cycle a sequence of five waves denoted with the letters P, Q, R, S T. Each of these waves represents the electric activity in the various phases of the cardiac cycle.

Further on, we present the modelling of the blood volume, if we administer a certain substance amount, then its passing speed will depend on its concentration, hence the volume at which it spreads in the deposit. This size is hard to determine. This is why Dost defined the amount of substance which would realise an initial concentration exactly defined in blood after the complete resorbtion and after the installation of a supposed equilibrium as dose. This initial fictional concentration in blood is denoted with **c.** It would be achieved at time **t = 0**, and at the time **t** the concentration would be $\mathbf{c}^*$. Then results the analogy with the formula of **c*** increase in relation of the reaction speed:

$$c^* = \frac{dc^*}{dt} = k \cdot (c - c^*)$$

and integrating:

$c^* = c.(1 - e^{-kt})$;

for the concentration decrease speed:

$$-\frac{dc^*}{dt} = k_2 \cdot c^*$$

integrate

$\mathbf{c^* = c.e^{-k_2.t}}$

If the two processes combine, it is mandatory that the concentration increase speed be proportional with the invasion constant $\mathbf{k_1}$, hence with the amount of substance still present in the storage:

$\mathbf{c.e^{-k_1.t}}$

from here:

$$\frac{dc_1^*}{dt} = k_1 \cdot c \cdot e^{-k_1 \cdot t}$$

The concentration decrease speed will be on its turn proportional with the elimination speed $\mathbf{k_2}$, hence with the present blood level:

$$\frac{dc_2^*}{dt} = -k_2 \cdot c_2^*$$

The amount of the two speeds gives the modification which is produced when the two processes take place simultaneously. For this care the relations are valid:

$$dc^* = dc_1^* + dc_2^*$$

$$\frac{dc^*}{dt} = c \cdot k_1 \cdot e^{-k_1 \cdot t} - k_2 \cdot c_2^*$$

The solution of this equation has the following expression:

$$c^* = \frac{c \cdot k_1}{k_2 - k_1}\left(e^{-k_1 \cdot t} - e^{-k_2 \cdot t}\right)$$

The clinical and hemodynamic study of the vascular diseases mentioned the participation of many of the circulatory territories (cerebral, coronary, renal) in these diseases. The spleen circulation is more accessible to the hemodynamic investigation means. Further on we present a method of exploration of the gastric circulation.

In order to apply the calorimetric principles for the measurement of the gastric blood flow, we made a

probe at whose end a 20 ml rubber balloon was attached. Inside the probe we introduced three thin tubes; two of them end inside the balloon and one crosses the balloon exiting it. At the end of one of the internal probes a thermistor was mounted, which can be placed in contact with a galvanometer. The external probe on whose end a clive was mounted serving at introducing in the stomach some pharmacological substances or for feeding. This way the test made can serve for the simultaneous measuring of the blood flow, the secretion and mobility of the stomach, before and after the administration of substances.

The principle lying at the base of the determination of the blood flow is the one of the calorimeter between the water in the balloon, the tissues of the stomach's walls and the blood that irrigates these tissues. Exchanges of caloric energy take place: at the beginning of the determination, the cold water from the balloon cools the organ's walls; they will be reheated by the flowing blood. Due to this heat transfer in the last analysis, the temperature of the balloon water will start to rise and it tends to equalise the one of the organ's wall.

There are two thermal systems with various temperatures: stomach (O) having the temperature $\mathbf{t_O}$ and the balloon with the temperature $\mathbf{t_B}$. An unknown amount of blood of a constant temperature passes through the stomach's capillary system. Thus, at the beginning the stomach temperature and the blood temperature ($\mathbf{t_S}$) are the same, but when the stomach gets in contact with the balloon, which has a lower temperature, then it tends to equalize the temperature value.

In the **dT** interval, the stomach wall passed an amount $\mathbf{Q_{OB}}$ to the balloon from the blood which passed through this portion in that period of time. The heating of the balloon is directly proportional with the amount of heat absorbed and inversely proportional with the balloon's thermal capacity:

$$dt_B = \frac{Q_{OB}}{C_B}$$

On the other side, $\mathbf{Q_{OB}}$ is proportional with the temperature difference, with the time interval and with the thermal transmission coefficient.

We can write a similar equation for the stomach as well. The two equations can be reduced to the following forms:

$$Q_{OB} = a(t_O - t_B)dT$$

$$dt_B = \frac{a(t_O - t_B)dT}{C_B}$$

where: $\mathbf{C_S}$ is the blood's thermal capacity which passes in a time unit through 1 $cm^2$ of the stomach's surface.

$$\frac{dt_O}{dT} = (-\frac{a}{C_O} - \frac{C_V}{C_B})t_O + \frac{a}{C_O}t_B + \frac{C_V}{C_O}t_V$$

$$\frac{dt_B}{dT} = \frac{a}{C_S}t_O - \frac{a}{C_B}t_B$$

In order to solve the problem we must find the solution of the non homogenous differential equation solutions first. So the solution of the non homogenous system will be:

$$t_O = t_S - d \cdot e^{-r_1 \cdot t} + d \cdot e^{-r_2 \cdot t}$$

$$t_B = t_S - d \cdot K_1 \cdot e^{-r_1 \cdot t} + d \cdot K_2 \cdot e^{-r_2 \cdot t}$$

The diagnostic of a chronic peripheral arteriopathy can be made from the characterisics of pain and in the presence of the trophic disturbances. The aggravation or the improvement of the circulation in the segment with ischemia can be also evaluated with a series of tests: pain apparition time, recolouring time, skin temperature, etc. In the physiopathology research of the circulation in arteriopathic people, when there are necessary arguments refering to the efficiency of new medicines or for the purpose of reestablishing the work capacity, the clinic diagnostic must be completed with laboratory samples: regional debt, peripheral arterial resistance, circulation time etc.

The muscular and tegument regional blood flow can be measured through several methods, some of them requiring special technical devices. The calorimetric method is based on measuring the heat being introduced in a certain amount of water which has known temperature. We know that this

heat derives from arterial blood and to a very little extent, from the local metabolism. Its measuring can be made with a normal double walls calorimeter and we measure the water temperature variations.

The technique has several phases: 1) the determination of the heat amount which transmits from the sick limb (it comes from the arterial blood) to the liquid environment; the calculation is made with the Fourier equation:

$$dQ = \chi \cdot \frac{dT}{dx} dS \cdot d\tau$$

where: **dQ** – transmitted heat amount; **χ –** thermal conductibility; **dT/dx** – temperature gradient; **dS** – transport surface; **dτ** – time interval. The determination of the heat amount which transmits from water to the environment is made with the formula:

$$Q = m \cdot c \cdot \Delta T$$

$$m = \frac{Q}{c \cdot \Delta t}$$

where: **Q** – heat amount; **m** – blood mass; **c** – specific heat; **Δt** – temperature difference.

Knowing the values of the previous formulas and the mass of blood circulated in that segment, we find out the segment's flow:

$$V_s = \frac{m}{\rho \cdot dt}$$

where: $\mathbf{V_s}$ – the segment volume in the time unit; **m** – blood mass; ρ – blood density; **dt** – time interval.

**References**


1. Vincze, J. The Capital Chapter of Biophysics. 5th. Ed. NDP P., Budapest, 2015.
2. Vincze, J.: The Biophysics is a Borderland Science. Second Ed. NDP P., Budapest, 2015.
3. Vincze, J.. Medical Biophysics. NDP P., Budapest**,** 2018.
4. Sarson, E., Cobelli, C.: Modelling Methodology for Physiology and Medicine. Elsevier P., 2014.
5. Vincze, J.: The Transport Phenomena and Cross-effects in the Living Systems. NDP P., Budapest, 2001.
6. Vincze, J.: Interdisciplinarity, NDP P., Budapest, 2007.
7. Vincze, J., Vincze-Tiszay G.: Biophysical model of active transport through vesicles. Medical Research Archives, 2020, 8., (4):1–9.
8. Vincze, J., Vincze-Tiszay G.: The Biophysical Modeling of the Transport Phenomena in the Living Systems. Technium, 2020, 2(4): 134–140.
9. Vincze, J.: Biophysics of the Apparatuses. NDP P. Budapest, 2020.
10. Vincze, J., Vincze-Tiszay. G.: The Biophysical Modeling of Transport Phenomena and of Crossing-effects in Living Organism. Research Aspects in Biological Sciences. 2022; 4., 48–56.
11. Vincze, J., Vincze-Tiszay, G.: The Biopsical Modeling of Psychological Aspects. Advances Social Sciences Research J., 2023., 9., 5:90–97.
12. Vincze, J., Vincze-Tiszay, G.: The Human Mind. Philosophy Study., 2023., 13., 2:60–67.


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